Detector Constructed From Electrically Conducting Fabric

The present invention relates to a detector constructed from electrically conducting fabric and configured to present a varying electrical characteristic in response to a mechanical interaction.

A fabric touch sensor for providing positional information is disclosed in United States Patent No 4,659,873 of Gibson. The sensor of Gibson is fabricated using two layers of fabric having conducting threads, where said conducting layers are separated by a resistive layer to prevent unintentional contact. The Gibson device is primarily an overlay for a visual display unit whereby the position of finger contacts may be identified in response to the display of representational icons, such as buttons etc. An electrical potential is applied across at least one of the layers and a voltage detected at a position of contact allows a position on the touch screen to be detected.

A problem with this configuration is that it is only capable of detecting a single touch and cannot identify two or more separate touches.

In some circumstances, it is desirable to provide a flexible detector constructed from electrically conducting fabric in which it is possible to detect two or more contact locations.

A proposal for achieving this is disclosed by the present applicants in British Patent application No. 2 341 932 and co-pending Australian patent application No. 48770/99, European patent application No. 99307539, Japanese Patent application No. 11-272513, Korean patent application No. 99-40363 and United States patent application no 09/298,172. In these co-pending patent applications, one of the conducting planes is divided into a plurality of smaller planes, the operation of which is then time multiplexed

so as to facilitate the detection of a plurality of mechanical interactions, provided that said interactions occur in different multiplexed regions.

A lower planar sheet is provided with connections at each of its corners to provide a two-dimensional co-ordinate position within the sheet area. An upper sheet is then divided into a plurality of portions and a mechanical interaction results in conducting planes of at least one of these portions being made active.

In order to achieve space division multiplexing of the regions, the electrical signals are time multiplexed such that operations upon each region are provided during a respective time slot. Each individual region is provided with its unique electrical connector established within the structure of this sheet.

Each output line associated with a region is provided with a respective buffering amplifier and a complete scanning cycle involves the application of a voltage between input terminals whereafter an output is considered from each of the individual output terminals.

A problem with this approach to providing a multiplexed sheet is that the construction of such a sheet is relatively difficult and thereby leads to significant constructional costs; thereby limiting its area of application. In addition, this approach requires the use of a 5-wire system, as distinct from the preferred 4-wire system, resulting in non-uniform electric fields and a requirement for compensation to be provided. This introduces further problems in terms of calibration and also in terms of loss of resolution.

An electrical switch using fabric elements is disclosed in British patent application No 1,308,575 in which conductive rows are made by coating portions of the fabric with an electrically conductive metal, such as

silver or chromium. Manual pressure applied at particular regions may be detected by the intersection of a particular row and column being brought into contact but the presence of a continuous metal layer significantly restricts the flexibility of the device as a whole. This is emphasised by the fact that the device is to be constructed upon a rigid board and as such many of the benefits from using a fabric material are effectively lost.

According to a first aspect of the present invention, there is provided a detector constructed from electrically conducting fabric and configured to present a varying electrical characteristic in response to a mechanical interaction, wherein a first conducting layer is displaced from a second conducting layer such that conduction between said layers results when said layers are mechanically forced together, characterised in that the first of said layers has a plurality of lengths of conductive yarn and a plurality of lengths of non-conductive yarn machined therein, such that at least one length of conductive yarn is electrically isolated from another of said lengths of conductive yarn, said conducting yarns in the first of said layers are electrically grouped to define a plurality of identifiable rows; each said identifiable row has a respective electrical conductor; and said identifiable rows define specific regions of the detector.

An advantage of this configuration is that each of the conducting layers may be manufactured as a homogenous sheet using conventional textile manufacturing techniques. Furthermore, when assembled in the form of a detector, the detector itself remains flexible and all of the advantages of its textile construction may be utilised.

The invention will now be described by way of example only, with reference to the accompanying drawings in which:

Figure 1 shows a woven fabric of a type suitable for application in a detector;

Figure 1A shows an alternative to the fabric of *Figure 1*, produced by a knitting process;

Figure 2 shows a plurality of warp filaments grouped together by a conductive track;

Figure 3 illustrates an example of a sheet fabricated using the technique illustrated in *Figure 2*;

Figure 4 shows use of the material identified in *Figure 3* for the manufacture of a five layer device;

Figure 5 shows an assembled device of the type shown in *Figure 4*;

Figure 6 details an interface circuit for connection to the detection device shown in *Figure 5*;

Figure 7 details an example of a pressure/location detection circuit that is incorporated into the interface circuit of *Figure 6*;

Figures 8A and *8B* detail schematically the pressure measurements that can be made by the location/pressure detection circuit identified in *Figure 7*;

Figure 9 is a flow chart illustrating a mode of operation performed by the PIC16C711 processor shown in *Figure 7*;

Figure 10 is a flow chart detailing the initialisation procedure performed by the PIC16C711 processor shown in *Figure 7*;

Figure 11 is a further flow chart detailing the detailing the configurations of the PIC16C711 processor for the collection of Z value data as indicated in step **902** of *Figure 9*;

Figures 12A and *12B* detail schematically the X and Y positional co-ordinate measurements that can be made by the location/pressure detection circuit identified in *Figure 7*;

Figure 13 is a flow chart detailing a further mode of operation of the PIC16C711 processor;

Figure 14 is a flow chart detailing the configuration of the PIC16C711 processor for the collection of X, Y co-ordinate positional data and Z axis data as indicated in step **1301** of *Figure 13*;

Figure 15 shows a detection device of the type shown in *Figure 5* being used on a hospital bed;

Figure 16 shows an exploded view of the conductive fabric layers of the hospital bed detector shown in *Figure 15*;

Figures 17A and *17B* show a computer monitor with a graphic display of data acquired from the device of *Figure 15*;

Figure 18 shows an alternative embodiment of the detector shown in *Figure 5* being used on a hospital bed;

Figure 19 is an exploded view showing the fabric layers of the embodiment shown in *Figure 18*;

Figure 20 shows a further embodiment of a detector in the form of a fabric keyboard being used by an operator;

Figure 21 is a perspective view of the fabric keyboard shown in *Figure 20*;

Figure 22 is an exploded view of the fabric keyboard detector showing the individual fabric layers;

Figure 23 is a plan view of the electrically conductive fabric layer **2201** shown in *Figure 22*;

Figure 24 is a plan view of the electrically conductive fabric layer **2202** shown in *Figure 22*;

Figure 25 is a plan illustration of the location of the keys of the fabric keyboard in relation to the regions into which the keyboard detector is divided.

Figure 1

A woven fabric is shown in *Figure 1* of a type suitable for application in a detector made in accordance with the present invention. The woven fabric has a warp made from single filaments of carbon coated nylon-6, available from BASF under the trademark "RESISTAT" and identified by the designation F901. F901 is a fibre produced primarily for use in static dissipation applications in fabrics. Many different sizes of filament may be employed, dependant upon the requirements of an application, and in this example the size of the filaments is twenty-four decitex, (twenty-four grams per 10,000m) presenting a diameter of fifty-two micrometers.

Weft fibres **102** are fabricated from a polyester yarn of similar dimensions to the warp. These polyester weft yarns are non-conductive such that the resulting fabric is conductive along the warp, in direction **103** but not conductive in the orthogonal weft direction, as illustrated by arrow **104.** Thus, due to the nature of the weave of the material, each conductive warp yarn **101** is separated from adjacent conductive yarns, even when flexed, due to the undulating nature of the weft yarn **102.** Thus, the fabric is composed of a plurality of lengths of conductive yarn and a plurality of lengths of insulating yarn, such that each length of conducting yarn is electrically isolated from adjacent lengths of conducting yarn.

As used herein, a yarn should be understood to include a spun thread having many fibres or a continuous fibre, possibly extruded from plastic etc. Thus, in this example, each length of the warp yarns is a continuous thread whereas the wefts **102** are spun from a plurality of threads.

An alternative to the fabric of *Figure 1* is shown in *Figure 1A*. *Figure 1A* provides a detailed view of a fabric **111** produced by a knitting process. Such a construction may be achieved by using either a warp knit or a weft knit process. The knitted fabric **111** is produced by knitting together lengths of conductive yarn **112**, **113**, **114** and lengths of non-conducting yarn **115**, **116**, **117** in a machining process. Therefore, in a similar manner to the fabric of *Figure 1*, the fabric of *Figure 2* contains lengths of conducting yarn (eg **113**) that are electrically isolated from adjacent conducting yarn (eg **112** and **114**) by non-conducting yarn (eg **116** and **117**).

The knitted fabric thus provides a layer having electrical conductivity in one direction along the layer, indicated by arrow **118**, which is defined by the alternating conductive and non-conductive yarn.

Figure 2

In the construction of a detector, a plurality of lengths of conductive yarn are selected for electrical connection to a conductive track. Therefore, a plurality of warp yarns, of the fabric of *Figure 1*, are electrically connected to a conductive track, as shown in *Figure* 2. In the weaving of fabric of the type shown in *Figure 1*, the warp threads are not physically grouped and no additional processes need to be performed to the general weaving process. The grouping is only defined by the electrical connection. In the

embodiment shown in *Figure* 2, all warp threads within a group are electrically connected such that, at a boundary, a warp thread will be connected to a particular electrical connector with the adjacent thread being connected to a different connector; it being noted that adjacent warp threads are electrically insulated from each other by the non-conducting weft threads. However, in an alternative embodiment, non-conductive warp threads could be introduced at group boundaries or gaps may be introduced such that some of the warp threads remain unconnected to an electrical connector. However, advantages in terms of continuity exist if all of the threads are electrically connected, particularly if the device is to be used as a single conductive layer (with the individual connectors being electrically connected together) so as to minimise the introduction of discontinuities.

Conductive track **201** has a conduction portion **202** and a attachment portion **203**. The attachment portion **203** makes physical and electrical contact with a set of conducting warp filaments **101**. The conduction portion **202** facilitates electrical connection to external devices. The conducting tracks **201** are applied to the conductive material and an insulating substrate **204** by a printing process, using a conductive ink such as that normally used in flexible printed circuit manufacture. Alternatively the conducting tracks may be fabricated from a highly conductive material, possibly fabricated exclusively from conductive filaments, and then attached to the substrate material and the conducting material by means of a conductive adhesive, such as conductive acrylic adhesive containing metallised particles. Alternatively, the conducting tracks may be fabricated from fabric coated with conductive metals, such as silver or nickel. Material

of this type is readily available and is used extensively for shielding equipment from electromagnetic interference. This too may be used in conjunction with a conductive adhesive.

Figure 3

Conductive track **201** represents one of many similar conductive tracks present within a fabricated sheet, of the type illustrated in *Figure 3*. In the example shown in *Figure 3*, seven attachment portions **203** and **301** to **306** are present each having respective conducting tracks printed or glued to substrate **204**. In this way, there is provided seven conducting bands **311** to **317**, with the material having a similar arrangement of attachment portions **321** to **327** at its opposite end. Thus, in this way, it is possible for an electrical current to flow through each of the conductive bands **311** to **317**, without conduction being made possible between the bands given that the material is not conductive in the orthogonal direction, that is along the direction of the wefts. The precise number of electrical connections formed to the fabric sheet may be varied from that shown in *Figure 3* depending on the type of detection device required.

In some applications, it is only necessary for the conductive warp threads to be connected at one end, given that a particular area may be identified by conduction through to a similar sheet, thereby identifying a particular row/column position. However, an advantage of providing electrical connections at both ends is that a voltage gradient may be applied across the layer and an accurate position within a particular region may be detected by measuring specific voltages. Furthermore, it is also possible for other properties of a mechanical interaction to be detected by

measuring other electrical properties such as the degree of current flow.

Figure 4

The fabricated material layer shown in *Figure 3* forms part of the five layer device of the type shown in *Figure 4*. The layer illustrated in *Figure 3* represents a top layer **401** of the five layer device illustrated in *Figure 4*. A similar layer is used for a bottom layer **402** where the construction is rotated through ninety degrees. Thus, the conductive regions **311** to **317** in top layer **401** present a plurality of conductive rows, with similar layer **402** presenting a plurality of conducting columns. In this way, specific regions (forty-nine in this example) may be identified within the device as being in a particular row in sheet **401** and in a particular column in sheet **402**. Furthermore, a mechanical interaction, such as a finger press or other compression, may result in a current flow within a particular area between conductive layers **401** and **402**.

The five layer device is completed by a central conductive layer **403** and intermediate insulating layers **404, 405**. The central conductive layer **403** is constructed by knitting a polyester yarn of twenty-four decitex filaments having a single conductive filament twisted therein, such that the conductive filament appears relatively randomly in the completed knitted product. In addition, the central conductive layer **403** has a conductance perpendicular to the plane of the device (in the z axis) that increases as it is placed into pressure thereby facilitating conduction between the layers during a mechanical interaction.

The insulating layers **404** and **405** are woven or knitted with a relatively wide spacing so as to ensure that the conductive layers are

separated while at the same time allowing conduction to take place when mechanical pressure is applied. The presence of these insulating layers ensures that the overall construction may be folded and flexed or wrapped around objects without causing the two conductive layers to be brought into contact and thereby producing an erroneous contact identification.

In an alternative embodiment, it is possible to fabricate a device using three layers, effectively removing layers **404** and **405**. To achieve this, conducting layers **401** and **402**, or the central conductive layer **403**, are fabricated in a way such that portions of the non-conducting fibres stand proud of the conducting fibres, thereby effectively introducing a degree of insulation in the z direction. This may be achieved by using weft fibres having a larger dimension than the warp fibres or alternatively by introducing other ways of making the weft fibres stand proud.

In a further alternative embodiment, the device is fabricated with only two layers **401** and **402**. In a similar manner to the three layered device, the layers **401** and **402** are fabricated using conducting and non-conducting fibres, such that the non-conducting fibres stand proud of the conducting fibres. The conducting fibres are thus recessed within the layers. The resulting assembly has disadvantages in use, in being more prone to outputting erroneous signals when flexed or folded. This disadvantage is minimised by increasing the depth of the recessing of the conductive fibres in each layer. However, this in turn makes the device harder to activate at low pressures.

The advantage of such an assembly is in its simplicity of construction. In fact such an assembly can be produced in a single pass on a weaving loom in the form known as a “double cloth”, where insulating weft

and conducting warp form an upper portion of the fabric, and a conducting weft and an insulating warp form a lower half of the fabric. The two portions are periodically attached by the inclusion of one of the insulating yarns from either portion, in the other portion. Insulating substrate material and conducting tracks are then applied onto the outside of the resulting fabric to complete the assembly.

Figure 5

Conducting tracks, such as track **201**, are covered by an insulating adhesive tape or alternatively by a printed insulating material. The layers shown in *Figure 4* are then assembled together, by a sewing operation, or alternatively by lamination, to form an assembled detection device **501** as shown in *Figure 5*. Wires are attached to the ends of the electrical track and then assembled together in the form of a cable **502** connecting the fabric device **501** to an interface device **503**. Interface device **503** includes a power switch **504** and a mode selection switch **506**. In addition, the interface device **503** includes an output socket **507** by which outputs generated by the interface device are transmitted to a further processor and/or a visual display unit. In response to a mode of operation selected by mode selection switch **506**, the output socket **507** provides an output representative of mechanical interactions occurring on the detector **501**.

Physically, the detector **501** appears to be a continuous sheet, without discontinuities. However, given the arrangement of electrical connectors, the sheet is effectively divided into a plurality of regions, a total of forty-nine in this example but the actual number present in any implementation is determined by the ultimate function that the detector is to

perform.

In a first mode of operation, selected by switch **506**, the detector operates in a substantially digital manner providing an indication as to whether a mechanical interaction has occurred at any particular region. Such a mode of operation, for example, facilitates an application in which the pressing of buttons is being detected.

In a second mode of operation, selected by switch **506**, it is possible to identify which region is undergoing a mechanical interaction and it is also possible to provide additional information about that interaction, such as the pressure of the interaction.

In a third mode of operation, it is possible to identify which region is undergoing a mechanical interaction and to provide additional information about that interaction, such as the pressure of the interaction, but it is also possible to locate the position of the interaction to a location within an identified region.

In a fourth mode of operation, the electrical connectors are effectively connected together such that the detector behaves as a single pressure sensitive sheet using analogue voltage variations to determine positions within the detector and current variations to determine the extent of the interaction. Under this mode of operation individual regions do not form part of the operational characteristic.

The interface device **503** is capable of performing the above modes of operation either by manual selection using the mode selection switch **506**, or by pre-programming or automatically selecting a mode of operation.

Figure 6

Interface device **503** is detailed in *Figure* 6. In addition to an output socket **507**, the interface device includes a detection processor **601**, a pressure/location detection circuit **602**, a switching circuit **603**, a multiplexing switch **604** having electrical connection input elements **605**, and an input socket **606**. Each of the seven conductive columns in layer **402** and each of the seven conductive rows in layer **401** has two wires associated therewith, therefore in this embodiment with forty-nine regions, there is a total of twenty-eight individual wires restrained within cable **502**. These wires are received by input socket **606** and are then fed individually to the electrical connection input elements **605** of multiplexing switch **604**. Multiplexing switch **604**, under the control of detection processor **601**, cyclically selects groups of four inputs during mode one, mode two or mode three operation, effectively resulting in a periodic scan of the forty-nine detector regions. The four inputs selected by multiplexing switch **604** are supplied to the pressure/location detection circuit **602** which, dependant upon the position of selection switch **506**, operates to obtain readings from the detector **501**. In mode four operation the multiplexing switch **604** connects all similar lines in parallel to present four lines to the location/detection circuit **602** relating to the whole of the device; with no cyclical operation between regions being performed.

When location detection is being performed, (mode one) it is only necessary for multiplexing switch **604** to connect a single connection from upper sheet **401** and a single connection from lower sheet **402** to pressure/location detection circuit **602**, at any one time. If, on viewing these two terminals, an open circuit is present (indicating that no current is flowing

from the upper sheet **401** to the lower sheet **402**), no mechanical interaction has occurred at the region under consideration. Alternatively, if a closed circuit is identified and current is flowing from the upper sheet **401** to the lower sheet **402**, this can be represented as a mechanical interaction and an output to this effect is supplied to switching circuit **603** which in turn conveys this information to the detection processor **601** and to output socket **507**. The detection processor **601** is therefore controlling the multiplexing operation and is then in a position to compare the configuration of the electrical connections formed to the detector with the resulting output from within a given region. Consequently, an output is constructed by the detection processor **601** showing a representation of the detector with indications as to where a detected mechanical interaction has taken place.

In modes two, three and four, information relating to pressure detection at individual regions (modes two and three) or pressure detection values for the whole of the detector (mode four) are also obtained by the pressure/location detection circuit **602** and supplied to the switching circuit **603** which in turn conveys this information to the detection processor 601 and finally to the output socket **507**. Output information is conveyed to a further processor and/or a display apparatus which produces a visual representation in response to the outputs received from the interface device **503**. The nature of the visual representation will be more complex for mode two, three and four operation compared to that required to illustrate mode one operation.

In mode two and mode three operation, multiplexing switch **604**, under the control of detection processor **601**, cyclically selects groups of four inputs, effectively resulting in a periodic scan of the forty-nine detector

regions. The four inputs correspond to two pairs of attachment portions, such that each pair corresponds to one of the conductive bands. The four inputs selected by multiplexing switch 604 are supplied to the pressure/location detection circuit **602**.

In mode two, the pressure/location detection circuit **602** provides a pressure detection value to the detection processor **601** via switching circuit **603**. In mode three, the pressure detection circuit provides the display processor **601** with a pressure detection value and also X and Y positional co-ordinate data relating to the position of mechanical interaction within the region being addressed.

In mode four operation, the conductive portions on each of the edges of layer **401** or **402** are electrically connected. For example, conductive portions **321** to **327** (as shown in *Figure 3*) are electrically connected by the multiplexing switch **604** and provide one of the four inputs to the pressure/location detection circuit **602**. The other three inputs are connected to the conductive portions corresponding to the other three such edges. The pressure/location detection circuit **602** detects pressure applied to the device **501** by a mechanical interaction and also the X and Y position of the mechanical interaction. Corresponding pressure and positional values are supplied by the pressure detection circuit to the switching circuit **603** and so to the detection processor **601**.

In modes one, two and three, the provision of a plurality of regions, each of which may independently provide information relating to a respective mechanical interaction via circuit **602**, allows the device to be used in many applications where a single interaction detector would not be suitable. Firstly, it would be possible to provide a detector with graphical

icons or buttons printed thereon which are then responsive to manual finger presses, in a situation where more than one finger press may be made; this exploits the provision of the mode one location detection operation operated by the location detection circuit **602**.

In another application, exploiting the pressure detection capability, it is possible to map degrees of pressure applied to each of the specific regions. This application is particularly useful when considering personal support appliances, such and beds. In one example, a device is used as a mattress cover for patients susceptible to pressure ulcers. A display device connected to the device provides an indication of areas where excessive pressure is being applied to the mattress and can also monitor movement of the occupant over time, such that the healthcare professionals may take appropriate action and thereby reduce further complications.

Figure 7

The location/pressure detection circuit **602** is detailed in *Figure 7*. The location detection circuit comprises a peripheral interface controller **701** which is connected to a serial communication output **702** and electrical connections **703**, **704**, **705** and **706** configured to supply and receive the necessary voltages via the multiplex switch **604**.

The peripheral interface controller (PIC) **701** is a programmable controller of the type PIC16C711. The PIC **701** operates under the control of a programme which controls the parameters of the detector which the pressure/location circuit **602** is configured to measure or detect. *Parameters under investigation will depend upon which mode of operation* is selected and will be discussed further in reference to *Figures 8* to *12*.

Under control of the PIC **701**, and dependant on the mode of operation, the necessary output voltages can be supplied to electrical connections **703**, **704**, **705** and **706** via pins one, two, ten, eleven, twelve and thirteen of the PIC. The PIC includes an analogue to digital converter which is used to process analogue voltages received at pins seventeen and eighteen. The input pins seventeen and eighteen receive outputs from high impedance buffers **709** and **710** respectively. The buffers **709** and **710** are half of unity gain operational amplifiers of the type TL062, and provide a high impedance buffer between the sensor output voltages and the PIC 701 input ports.

Connection to pins one and two occurs via resistors **708** and **707** respectively. Resistors **708** and **707** are selected according to the resistance of the detector as measured from a connector attached to one fabric layer **401** to a connector attached to the second fabric layer **402** while a typical mechanical interaction pressure is applied to the corresponding area of the detector under investigation. A value of 10Kohms is typical for resistors **708** and **707**.

The PIC **701** has an external crystal oscillator (not shown) running at 4 MHz connected across pins fifteen and sixteen. Positive five volts is supplied to pin fourteen and ground is connected to pin five. Pin four (the internal reset input) is held at positive five volts via a series resistor of 100ohms.

The program running on the PIC **701** will determine the operational mode of the interface device **503** and determine the output measured by pressure/location detection circuit **602** within a region of the detector selected by the multiplex switch **604**.

The four modes of operation of the interface device **503** have already been referred to. A mechanical interaction results in the initiation of current flow from the first electrically conductive layer **401** to the second electrically conductive layer **402**. Accordingly, all four modes of operation require the detection of a pressure within a selected region of the detector. In mode one operation, the pressure/location detection circuit **602** provides an output indicating whether a pressure has been detected within a selected region of the detector. In modes two, three and four the pressure/location detection circuit **602** provides an output comprising a quantitative measure of the pressure detected within a selected region of the detector.

Figures 8A and 8B

A procedure for measuring the pressure and or area of a mechanical interaction is detailed in *Figures 8A* and *8B*. An area of the conductive fabric layers **401** and **402** to which voltages are being supplied via multiplexing switch **604** are represented schematically by potentiometers **801** and **802** and the resistance of the conductive path between the outer layers at the location of the applied force is represented by variable resistor **803**.

A first measurement of the pressure of a mechanical interaction is shown in *Figure 8A*. Five volts are applied to connector **706**, while connector **705** remains disconnected. Connector **703** is connected to ground via a resistor **707** of known value. Thus current flows from connector **706** through a first part of layer **402** as represented by a first part **804** of the potentiometer **802**, through the conductive path indicated by

variable resistor **803** having resistance Rv, through a first part of layer **401**, indicated by a first part **805** of potentiometer **801** and through the known resistor **707**. The voltage, V1 appearing at connector **703** is measured and since this is equal to the voltage drop across resistor **707**, V1 is directly proportional to the current flowing from connector **706**.

Since the resistances of parts **804** and **805** vary in relation to the mechanical interaction it is desirable to perform a second measurement of Rv. A second measurement of Rv can be performed as shown in *Figure 8B.* Five volts are applied to connector **704**, while connector **703** is disconnected. Connector **705** is connected to ground via a resistor **708** of known resistance. The voltage V2, dropped across resistor **708** is measured. Voltage V2 is directly proportional to the current flowing through a second part of layer **401** indicated by a second part **806** of potentiometer **801**, through the conductive path indicated by variable resistor **803** having resistance Rv, through a second part of layer **402** indicated by a second part **807** of potentiometer **802** and through resistor **708**.

The sum of the resistance of first part **805** and second part **806** of potentiometer **801** is approximately equal to the resistance between connector **704** and **703** on layer **801**, and is therefore substantially constant during the measurements, since they occur in rapid succession. Similarly the sum of the resistance of first part **804** and second part **807** of potentiometer **802** is approximately equal to the resistance between connector **706** and **707** on layer **802**, and is also substantially constant during the measurements. As a result, the relationship **810** exists between the resistance Rv, of the conductive path between the outer layers, and the measured voltages V1 and V2. i.e. the resistance Rv between the outer

layers is proportional to the sum of the reciprocal of voltage V1 and the reciprocal of voltage V2. The voltages are used to calculate a Z value which is indicative of the pressure applied in the Z axis to the fabric planes.

Depending upon the type of sensor used the resistance Rv depends upon area of the applied pressure or a function of the area and the force as illustrated by relationship **811**. Thus from the voltage measurements V1 and V2 an indication of the pressure with which the mechanical interaction is applied, or an indication of the area and the applied force may be determined.

Figure 9

An example of the program running on the PIC **701** of the pressure/location circuit **602** during mode one and two operation (where only pressure is determined) is detailed in *Figure 9*. At step **901** the hardware is initialised and this process is detailed later in reference to *Figure 10*. At step **902** the pressure/location detection circuit **602** measures values of voltages V1 and V2 (as described in reference to *Figure 8*) and calculates a Z value of the interaction. The details of step **902** are described later with reference to *Figure 11*. At step **903** a question is asked as to whether the Z data is greater than a predetermined value. If the answer to this question is no then the program returns to step **902**. Thus the circuit measures Z values until a Z value greater than a predetermined value is detected. If the answer to the question at step **903** is yes then, in mode one operation, an output is produced that is indicative of a mechanical interaction at step **904**. In mode two operation, the circuit measures the necessary voltages and calculates a Z value at step **904** and

provides a quantitative output indicating the magnitude of the applied pressure.

Once an output has been provided, the program then returns to step **902** and looks for an indication of a further mechanical interaction. For example, in mode two operation, the multiplexing switch **604** under the control of detection processor **601** will configure the connections made to the detector so that a further area of the detector is subsequently selected and the pressure/location detection circuit **602** will monitor that further area for an indication of a mechanical interaction.

Figure 10

Step **901** of *Figure 9* is shown in further detail in *Figure 10*. Within the initialisation step **901**, at step **1001** the interrupts are cleared and then at step **1002** pins seventeen and eighteen are set up as analogue to digital converter inputs. The microports of a PIC16C711 may be configured as low impedance outputs or high impedance inputs. When in high impedance input mode, pins seventeen and eighteen can be programmed to connect via an internal multiplexer, to the analogue to digital converter. At step **1003** the ports which are to be used as inputs or outputs are configured in their initial state. At step **1004** all system variables are cleared and all interrupts are disabled.

Figure 11

Step **902** of *Figure 9* is shown in further detail in *Figure 11*. Within step **902**, at step **1101**, the ports corresponding to pins two and ten are reconfigured as output ports and at step **1102** pin two is set to zero while

pin ten is set to positive five volts. Thus connector **703** is grounded via resistor **707** and five volts are applied to connector **706**. At step **1103** a time delay, (typically of two hundred and fifty microseconds in a sensor measuring one hundred millimetres by one millimetres with an outer layer resistance of 3.5Kohms) is provided to allow voltages to settle before the voltage at pin seventeen is measured and stored as detailed in step **1104**. Thus voltage V1 present at connector **703** is measured and stored.

At step **1105** pins two and ten are reconfigured as high impedance inputs while pins one and twelve are reconfigured as low impedance outputs. At step **1106** the voltages the voltages on pins one and twelve are set to zero and positive five volts respectively. Thus connector **705** is grounded via resistor **708** while five volts are supplied to connector **704**. A suitable time delay, equivalent to that at step **1103**, is provided at step **1107** before the voltage at pin eighteen is measured and stored at step **1108**. Thus the voltage present on connector **705** is measured and stored as voltage V2. At step **1109** a Z value is calculated from stored voltages V1 and V2, and then stored. The pins one and twelve are reconfigured back to their initial state of high impedance inputs at step **1110**.

During mode three operation, the circuit is configured to detect whether a mechanical interaction has occurred within a region and to provide a calculation as to the position of the mechanical interaction (i.e. the x and y positional co-ordinates of an interaction) within an area of the detector under investigation, in addition to calculating a further property of the mechanical interaction, such as pressure and/or area. Similarly, in mode four operation all the connections to the fabric planes **401** and **402** are connected so that the detector operates as a single pressure sensitive

sheet. The x and y co-ordinates of a mechanical interaction on the detector are determined by the pressure/location detection circuit **602** in addition to determining a Z co-ordinate value as necessitated by mode one and mode two operations.

Figures 12A and 12B

A procedure for measuring pressure and/or area of a mechanical interaction (or Z axis data), is described in reference to *Figures 8A* and *8B*. A procedure for determining the position of a mechanical interaction within an area of the detector under investigation is illustrated in *Figures 12A* and *12B*.

Figure 12A details the application of a voltage to an area of fabric layer **402** which is represented as potentiometer **802**. The corresponding area of fabric sheet **401** selected to detect an output voltage or have a voltage applied thereto is represented by potentiometer **801**. A first position measurement is made by applying a voltage of five volts to connector **705** whilst **706** is grounded. As a result a potential gradient is produced across layer **402**. A voltage measurement is made at connector **703** using a high impedance device and so the voltage appearing on layer **401** at the position of the applied force **1201** is determined. This voltage, V3 is directly proportional to the distance of the centre of the applied force from the electrical contact connected to voltage input **706** and indicates its x axis position.

A further measurement is shown in *Figure 12B*. Five volts are applied to connector **703** and connector **704** is grounded. A voltage measurement is made of voltage V4 appearing at connector **705**. Voltage

V4 is directly proportional to the distance of the centre of the applied force from the electrical contact connected to voltage input **704** and indicates its Y axis position shown at **1202**. Therefore voltage V3 and V4 provide information as to the two dimensional position of the applied force on the sensor within the area of fabric sheets **401** and **402** under investigation, i.e. voltages V3 and V4 represent X and Y values for the centre of the position of the applied force.

Figure 13

An example of a program that runs on the PIC **701** is shown in *Figure 13*. Steps **901**, **902** and **903** have already been described in reference to *Figures 9*, *10* and *11* as these steps are common to all four operational modes of the interface device **503**. Accordingly, the PIC is programmed to collect Z data (step **902**) and to determine whether the collected Z data is greater than the pre-set lowest acceptable threshold value (step **903**). In mode three operation, if the answer to the question at step **903** is yes then the circuit measures voltages V1,V2,V3 and V4 (as described in reference to *Figures 8* and *12*) at step **1301**. Step **1301** is described later in more detail with reference to *Figure 14*. At step **1302** a question is asked as to whether the calculated Z value is still above the predetermined value. If the question is answered in the affirmative, a further question is asked at step **1303** as to whether enough samples have been obtained. Typically, between three and ten sets of samples are taken, with lower numbers of sets of samples being taken when a fast response time is required. If the answer to the question at step **1303** is no, then the program returns to step **1301** and a further set of measurements are made. When

the answer to the question at step **1303** is yes, or when the answer to the question at step **1302** is no, then the program calculates average values of the samples of the voltages V3 and V4, and of the values of Z which have been collected. Thus, the program measures a predetermined number of voltages before finding the average values, or if the Z value drops below a predetermined value, the average values are calculated immediately. By using the average of a number of samples the effect of mains power electromagnetic interference or other such environmental noise may be minimised.

A simple calculation to find an 'average' value for say the X value, is to find the median of the maximum and minimum values of the stored values V3. i.e. a 'smoothed' value for X is found by adding the maximum stored value of V3 to the minimum stored value of V3 and dividing the result by two.

To further improve accuracy, values of X, Y, and Z that differ by a large amount from their immediately preceding and immediately subsequent values are excluded from the calculations of the average. In addition, known methods of eliminating mains electricity supply interference may be applied to the signals received from the sensor.

At step **1305** the averaged values for V3 and V4 representing XY positional co-ordinates and the averaged values of the Z data are output at the serial communication output **702**. The program then returns to step **902** and looks for an indication of further mechanical interactions.

Figure 14

Step **1301** of *Figure 13* is shown in further detail in *Figure 14*. Within step **1301**, at step **1401** a Z value is collected in the same manner as at step **902**. At step **1402** pins one and two are reconfigured as high impedance inputs and pins ten and eleven as low impedance outputs. At step **1403** pin ten is set to zero volts and pin eleven is set to positive five volts. Thus five volts are supplied to connector **705** while connector **706** is grounded. A delay is then provided at step **1404**, (of typically one millisecond for a device measuring 100mm by 100mm) to allow voltages in the sensor to settle before the voltage on pin seventeen is measured at step **1405**. Therefore a voltage V3 present on connector **703** is measured which provides an indication of the X position of the applied force.

Pins ten and eleven are then reconfigured as high impedance inputs and pins twelve and thirteen are reconfigured as low impedance outputs at step **1406**. The voltage on pin twelve is then set to zero while the voltage on pin thirteen is set to five volts at step **1407**. Thus five volts are supplied to connector **703** while connector **704** is grounded. A time delay is provided at step **1408**, similar to that at step **1404**, before the voltage appearing at pin eighteen is measured at step **1409**. Thus a voltage V4 present on connector 705 is measured which provides an indication of the Y position of the applied force. Pins twelve and thirteen are then reconfigured back to their initial state of high impedance inputs.

Therefore by the method described with reference to *Figures 8* to *14*, in mode three and mode four operation, the pressure/location detection circuit **602** is able to make voltage measurements V3 and V4 which provide an indication of the X and Y co-ordinate position of the force applied to a fabric sensor within an area, and measure voltages V1 and V2 which are

proportional to currents passing through the sensor and provide information as to a second characteristic of the applied force. The second characteristic may be the pressure with which the force is applied or a combination of the size of the force and the area. Furthermore, the pressure/location detection circuit **602** combines the voltages V1 and V2 to determine a Z value representative of the second characteristic.

Consequently, in both mode three and mode four operation, the pressure/location detection circuit **602** provides output data representative of X and Y position of the applied force and the Z value. However, in an alternative embodiment the pressure/location detection circuit **602** provides output data corresponding to the measured voltages V1, V2, V3 and V4.

Figure 15

A detection device of the type shown in *Figure 5* is shown used on a hospital bed **1501** in *Figure 15*. The detection device **1502** is positioned on top of the mattress of the bed, forming part of a mattress cover. The device may be covered with conventional hospital bed linen although for the purpose of illustration no bed linen other than the mattress cover and a pillow have been shown in *Figure 15*. Consequently, in normal use of the detector **1501**, the patient would not reside directly on the detector and would be electrically insulated from the upper electrically conductive fabric layer. The detection device **1502** is connected to the interface device **503** (not shown in *Figure 15*) the output **507** of which is connected to a computer **1503**. A monitor **1504**, connected to the computer, provides a graphic display of the information provided by the detection device. In an alternative embodiment, data from the output **507** is sent via modem to a

remote monitoring point.

A bed ridden patient **1505** is shown in a seated position on the detector **1502**. A problem of such patients, particularly those of limited or no self-manoeuvrability is the formation of pressure ulcers caused by prolonged periods of pressure applied to one part of the body. The patients must be continuously monitored by nursing staff, and their position altered, in order to prevent the ulcers occurring. Information regarding the magnitude of the pressure applied to the body, the location on the body to which that pressure is applied and the duration of that pressure could assist the nursing staff to monitor the patient and manage the patient's movement.

The detection device **1502** differs from that of *Figure 5* in that it has a bottom layer which includes only four conductive bands and not seven. Therefore the detection device has effectively twenty-eight individual regions. For the purpose of illustration only, dotted lines across detection device **1502** indicating the effective division of the detector in to twenty eight regions are included on *Figure 15*.

The duration over which data is collected may be long in this application, since the time over which the pressure is applied to the patient by the bed are very long in comparison to the cycling period of the interface device. Periodically, therefore, the interface device, operating in mode two or three, provides the computer with information regarding the pressure applied to the bed by the patient through each of the twenty-eight regions of the device **1502**. Preferably, in this application, the device is operated in mode three, and so it will also supply information as to where within each region the pressure is centred.

Figure 16

An exploded view of the fabric layers of the fabric sensor **1502** are shown in *Figure 16*. The structure shown in *Figure 16* is analogous to that shown in *Figure 4*. The detector has an upper electrically conductive fabric sheet **1601** and a lower electrically conductive fabric sheet **1602** separated from the upper fabric sheet **1601** by central conductive layer **1603** and intermediate insulating layers **1604** and **1605**. The layers **1603**, **1604** and **1605** are equivalent in function to layers **403**, **404** and **405** shown and described in reference to *Figure 4*.

The upper fabric sheet **1601** has a first series of conductive tracks **1606** attached along one edge of the fabric sheet and a second series of conductive tracks **1607** attached along the opposite edge of the upper fabric sheet. Electrical contact is made with the first and second series of conductive tracks via cables **1608** and **1609** respectively which are merged and form a connection with the interface device **503**. The first and second series of conductive tracks **1606** and **1607** have seven corresponding conduction portions (not shown) which form electrical contact with the fabric layer so as to define seven conductive columns as illustrated by the dotted lines traversing the upper fabric layer **1601**. Each conductive column is capable of having a voltages independently applied thereto during the operation of the detector.

The lower fabric sheet **1602** has a third series of conductive tracks **1609** along one edge of the fabric sheet and a fourth series of conductive tracks **1610** along the opposing edge of the fabric sheet. Electrical contacts are made to the third and fourth series of conductive tracks via cables **1611**

and **1612** respectively. The third and fourth conductive tracks **1609** and **1610** define four corresponding conduction portions (not shown) which form electrical contact with the fabric layer so as to define four conductive rows as illustrated by the dotted lines traversing the lower fabric layer **1602**. The electrically conductive rows of lower fabric sheet **1602** are arranged perpendicularly to the columns defined by upper fabric sheet **1601** as previously described. Accordingly, the warp conductive fibres of layer **1601** are arranged so as to conduct along the length of the columns indicated by the dotted lines and the conductive fibres of fabric layer **1602** are arranged to conduct along the length of the rows as indicated by the dotted lines.

In mode two operation the detector operates to provide an indication of the pressure within each region of the detector. An example of a display of an output in response to a mechanical interaction as shown on monitor **1504** of *Figure 15* is shown in *Figure 17A*. The monitor provides a graphical display of the data stored by the computer **1503**. The display shows a graphic representation of the detection device **1501** divided into the twenty-eight individual regions. The bed-ridden patient **1505** shown sat up in bed **1501** of *Figure 15* forms contact with the detector at the position of the buttocks and the heels of the feet.

Figure 17

The mechanical interactions thus formed between the patient and the detector are shown graphically on grid display **1701**. Mechanical interactions are shown as occurring in regions **1702** and **1703** which correspond to the contacts formed by the right and left buttocks respectively and **1704** and **1705** which correspond to the contacts formed by the right

and left heels of the patient respectively. A mechanical interaction within a region is indicated on the grid display (in mode two operation) as a dot within the centre of the region, such as that shown at **1706.** The pressure measured within that region is represented by a circle, such as that shown by **1707**, the diameter of which is directly proportional to the extent of the pressure applied. It can therefore be seen from *Figure 17A* that the occupier of the bed **1505**, in this example, is exerting more pressure on the right buttock and heel as indicated by the larger diameter circles present in regions **1702** and **1704** as compared with the pressure exerted by the left buttock and heel in regions **1703** and **1705**. Such a situation would arise when, for example, the occupier leans to the right hand side. Further information may be displayed such as chart **1708** which shows the variation of pressure over time within a given region, in this case region **1704**.

An example of graphic display of an output obtained during mode three operation is shown in *Figure 17B*. Monitor **1504** shows a grid display **1701** corresponding to the twenty eight regions of detector **1502**. In addition to showing the pressure of a mechanical interaction within a region as discussed in reference to *Figure 17A*, during mode three operation, the position of the centre of the mechanical interaction is also determined within a region. The patient **1505** exerts a pressure within the areas **1702** to **1705** as previously described. The position of the centre of force exerted by the patient's right heel within the region **1704** is shown at square **1706** which in this display is not central to this region. Similarly, the position of the right and left buttocks and the left heel within the respective regions **1702, 1703** and **1705** is also shown. As for *Figure 17A*, the pressure is represented by the diameter of circle **1707** displayed around the centre position of

interaction. In addition further time related pressure information may be displayed as shown in chart **1708** relating to the pressure recorded over time within the selected region **1704**.

Figure 18

An alternative embodiment of a detector according to the present invention incorporated into a mattress cover is shown in *Figure 18*. As before, the hospital bed **1501** has a detector **1801** incorporated into the mattress cover and the detector is connected to the computer **1503** via an interface device (not shown) and cable **1802.** A monitor **1504** displays data collected and stored by the computer **1503.** The detection device is divided into just seven regions **1803** to **1809** in the form of seven conductive bands as illustrated by the dotted lines shown on the detector **1801.** This represents an alternative configuration of the device which, in this application, will correspond to specific regions of a patients body. For example, for a typical adult lying down on the bed **1501**, region **1803** would correspond to the pressure exerted via pillow from the head region of the patient and region **1804** would correspond to the neck and upper shoulders of the patient. Similarly, region **1806** may correspond to the lower back and region **1808** or **1809** would correspond to the patients' feet. In this regard, the patients' body is effectively segmented into regions corresponding to the regions defined by the detector within which pressure can be recorded and monitored to alert hospital staff to any regions of the body exposed to prolonged contact pressure that may give rise to a pressure sore. It will be appreciated that the number and dimensions of the individual areas may be varied to effectively segment the patients' body as desired.

Figure 19

Figure 19 shows an exploded view of the detector **1801** shown in illustrated in *Figure 18*. The upper fabric layer **1601**, central conductive layer **1603** and intermediate insulating layers **1604** and **1605** are identical to those shown in *Figure 16*. The difference between the detectors occurs in the lower electrically conductive fabric sheet **1901**. The lower fabric sheet only comprises one conductive band instead of the four conductive bands which the fabric sheet **1602** of *Figure 16* comprised. The lower conductive layer may be conductive in both the warp and the weft directions. In such a case, the lower fabric sheet would, therefore, be conductive in all directions.

Information regarding the pressure with a region is again preferably collected during mode two or three operation and may be displayed in a similar manner to that shown in *Figures 17A* and *17B* with the grid display **1701** appropriately amended to illustrate seven horizontal columns only. All other features of the display shown in *Figures 17A* and *17B* and described in the corresponding description would be equally applicable to the display of the outputs from detector *1801*.

Figure 20

A further detector according to the present invention is shown, in use, in *Figure 20* embodied in the form of a fabric keyboard. In *Figure 20* an operator **2001** is shown working within a confined space of brief case **2002** supported on table top **2003**. Such a circumstance is likely to occur in the case of a worker travelling by train or working in an out of office location. The operator **2001** is interacting with the fabric keyboard detector **2004**

which is connected via interface device **503** to a hand-held processor **2005.** An example of a suitable hand-held processor would be a Palm[RTM] Vx processor manufactured by Palm Inc. By pressing key representations on the fabric keyboard **2004**, the operator **2001** can input data items into the hand-held processor **2005** which are displayed on the screen **2006**. It is an important feature of the present invention that the fabric keyboard **2004** is flexible so as to enable convenient operation of the fabric keyboard in a variety of locations and to enable convenient storage of the keyboard.

Figure 21

The fabric keyboard detector **2004** is shown in *Figure 21*. The fabric keyboard **2004** has key identification icons **2101** printed onto the upper surface **2102** of the detector. The key identification icons enable the operator to make a specific selection corresponding to the desired alpha numeric data input required. The upper fabric surface **2102** is an insulating layer configured to prevent direct contact between the operator and the electrically conductive fabric layers of the detector.

Voltages are applied to the detector and voltage outputs detected by interface device **503** via cable **2103** which connects to the fabric keyboard **2004** by connection port **2104.** Output cable (not shown) provides outputs from the interface device to the palm processor **2005** of *Figure 20* (not shown in *Figure 21*).

Figure 22

An exploded view illustrating the fabric layers that form the fabric keyboard detector **2004** is shown in *Figure 22*. The device has a first

electrically conductive fabric layer **2201** and a second electrically conductive fabric layer **2202**. The structure of these fabric layers will be described in more detail in reference to *Figure 23* and it will suffice to mention at present that electrically conductive layer **2201** has conductive track assemblies **2203** and **2204** positioned along opposing edges of the fabric layer so as to effectively divide the fabric layer into a series of conducting columns between conductive track assemblies **2203** to **2204**. Similarly, electrically conductive layer **2202** has conductive track assemblies **2205** and **2206** along opposing edges of the fabric layer and arranged perpendicular to the conductive track assemblies of layer **2201** so that fabric layer **2202** is effectively divided into a series of conducting rows across the fabric layer from conductive track **2205** to **2206**, the conducting rows being perpendicular to the conductive columns of the upper layer **2201**. The respective conductive tracks of layers **2201** and **2202** are fed into connection port **2104**.

The seven layer detector device also includes a central conductive layer **403** and intermediate insulating layers **404** and **405** which have previously been described in reference to *Figure 4*.

A top insulating layer **2102** is also included in the device. This is a woven layer of insulating fabric onto which a "QWERTY" keyboard outline **2101** has been printed on the upper surface. A bottom insulating layer **2209**, of woven fabric, completes the device. Layer **2209** supports an array of key registration devices **2210** in the form of raised portions, which are arranged so that each device **2210** is aligned with the centre of a QWERTY key outline **2101** on layer **2102**. The purpose of the key registration devices **2210** is to enable the operator to positively identify that a key has

been pressed by providing tactile feedback.

Figure 23

The first electrically conductive layer **2201** is shown schematically in *Figure* 23. The fabric layer comprises a key detection area **2301** which corresponds to the area of the keyboard detector within which the key presses are to be detected. The remaining portions of the fabric layer comprise the conductive tracks that form electrical connections between the detection area **2301** and the interface device **503**. The conductive track assembly **2204** shown in *Figure 22* is shown in *Figure 24* as individual conductive tracks having respective attachment portions **2302** to **2317** along an edge of the detection area **2301**. The conduction portions of each conductive track are grouped together and received within the connection port **2104** shown in *Figures 21* and 22. In addition, the conductive track assembly **2203** shown in *Figure 22* is also shown in *Figure 24* as individual conductive tracks having respective attachment portions **2318** to **2333** along the opposing edge of the detection area **2301**. The conduction portions of each conductive track are also grouped together and received within the connection port **2104** shown in *Figures 21* and *22*. The conduction portions are electrically connected via a cable to the interface device **503** shown in *Figure 21*.

The conductive warp fibres extend perpendicularly across the detection region **2301** from the attachment portions **2302** to **2317** and **2318** to **2333**, thus defining sixteen narrow conductive columns. The columns, for example **2340**, **2341** and **2342**, are shown by the dotted lines across the detection area **2301**.

Figure 24

The second electrically conductive layer **2202** is detailed in *Figure 24*. The second conductive layer has a corresponding detection area **2401** which, in this embodiment, is exactly the same dimensions as the detection area **2301** of fabric layer **2201**. The conductive track assembly **2205** shown in *Figure 22* is shown as individual conductive tracks having attachment portions **2402** to **2406** attached along an edge of the detection area **2401**. The respective conductive portions are grouped together and extend into the connection port **2104** where electrical connection to the interface device is made. Similarly, conductive track assembly **2206** as shown in *Figure 22* is shown as the individual conductive tracks having attachment portions **2407** to **2411** formed along the opposing edge of the detection area **2401**. Accordingly, the detection area is divided into five independent electrically conductive rows, for example rows **2420** to **2424**, as indicated by the dotted lines. As previously described in reference to the bed mattress embodiment shown in *Figures 15* to *17*, the conductive fibres of the second conductive layer **2202** are arranged at ninety degrees to the conductive fibres of the first conductive layer **2201** such that, in effect, the second layer is conductive in a direction perpendicular to that of the first fabric layer. Hence, the conductive rows of the second layer **2202** (for example **2420** to **2424**) are arranged perpendicularly to the conductive columns (for example **2240**, **2241** and **2242**) of the first electrically conductive layer **2201**. In the assembled detector, therefore, the intersections between the respective rows and columns effectively divides the detection area into eighty (equal to 16 x 5) individual regions. Furthermore, a mechanical interaction, such as a

finger press or other compression, may result in a current flow within a particular regions between conductive layers **2201** and **2202**.

Figure 25

Figure 25 shows a plan view of a portion of the detector showing the printed key identification icons **2101** of the upper layer **2102** of the fabric layer. Superimposed over the key identification icons are dotted lines indicating the columns and rows formed across the detection portions **2301** and **2401** of the first and second electrically conductive layers and the key registration devices **2210** positioned on the lower layer of the detector (as detailed in *Figure 22*). The five conductive rows **2420** to **2424** of layer **2202** and three of the conductive columns **2240** to **2242** of layer **2201** are shown in *Figure 25*. Each intersection of a row and a column defines a separate region of the input device and each region corresponds to one of the QWERTY keys printed onto the top layer **2102**. For example, a key outline **2501**, corresponding to the key graphically labelled "2", corresponds to the intersection of row **2424** and column **2240**, and key outline **2502**, corresponding to the key labelled "R", corresponds to the intersection of row **2423** and column **2242**.

Each key outline is arranged to be symmetrically positioned above a key registration device **2210** on layer **2209**. For example, key outline **2501** is positioned symmetrically above key registration device **2503**.

As shown in *Figure 25*, the key outlines are arranged in a staggered manner, such that for the alpha-numeric keys, the centre of a key on one row is aligned with the gap between the keys on the row below. For example, key outline **2501**, is located such that its centre is aligned with the

gap between key outlines **2504** and **2505**. Therefore, the key outlines do not correspond exactly with the conductive band intersections. However, the key registration device for a particular key is located within the area defined by the key outline and the area defined by the corresponding conductive band intersection. Therefore, when a user presses a key, for example **2501**, because the key registration device (in this case **2503**) is located within the corresponding intersection of bands, (in this case bands **2240** and **2424**) the conducting layers **2201** and **2202** are electrically connected at the correct intersection.

Figure 25 also shows key outline **2510** and part of outline **2511** corresponding to the "Alt" key and "Spacebar" respectively. Since they are keys of extended length, the respective key registration devices **2520** and **2521** are extended in a corresponding manner. Unlike key registration device **2503**, the key registration devices **2520** and **2521** are solid strips of plastic glued to layer **2209**. Therefore, devices **2520** and **2521** only provide tactile feedback in respect of position of the key and do not deform under pressure in the manner of device **2503**.

The fabric keyboard detector embodiment of the present invention can be operated, preferably in mode one whereby the region within which a mechanical interaction is detected is determined by the multiplexing operation. It is preferable as there is only a requirement to detect whether a key press has occurred within a specific region and, in this embodiment, no further information regarding the nature of the mechanical interaction is required. It must be noted that in mode one operation where only the presence or absence of any current flowing from electrically conductive layer **2201** to layer **2202** or vice versa is detected there is no specific

requirement for an attachment portion of a second conductive track assembly (for example **2203** and **2206**, *Figure 22*) on the opposing edge to a set of first attachment portion of a given column (for example **2204** and **2205**, *Figure 22*). Mode three operation could facilitate the incorporation of more than one key registration within a given region with the interface device with the capacity to distinguish which key has been pressed, but such an arrangement would have the disadvantage of not being able to distinguish two such keys when pressed simultaneously.

Due to the large number of individual regions incorporated into the fabric keyboard embodiment, it will be appreciated that to individually time multiplex all eighty regions of the detector may take a prolonged period. This may be a disadvantage when, for example, a trained speed typist is using the keyboard. Accordingly, a mechanism by which the detector can more rapidly identify the region within which a mechanical interaction has occurred utilising a reduced number of scanning procedures would be a distinct advantage.

An example of such a mode of operation is illustrated in *Figure 25* and the following description. The interface device **503** must identify a press on the fabric keyboard **2004**. When the detection area of the QWERTY keyboard is pressed, then the interface pressure/location detection circuit **602** provides an output identifying the location of the one or two keys which have been pressed.

In the initial state, however, the multiplex switching circuit **604**, under the control of detection processor **601**, connects a single connection of the pressure/location detection circuit **602** to all sixteen attachment portions **2302** to **2317** on one side of the layer **2201**, and a second single

connection to all five attachment portions **2402** to **2406** on one side of layer **2202**. If, on viewing these terminals, an open circuit is present, no mechanical interaction has occurred on the input device. Alternatively, if a closed circuit is identified, this indicates the presence of a mechanical interaction and an output to this effect is supplied to the switching circuit **603** which in turn conveys this information to the detection processor **601** and to output socket **507**.

On detection of a mechanical interaction, the multiplex switching circuit **604** under the control of detection processor **601**, maintains the single connection of the pressure/location detection circuit **602** to all five attachment portions **2402** to **2406** on one side of the layer **2202**, and a second single connection is made from the circuit **602** to the leftmost eight of the attachment portions (**2302** to **2309**) on one side of layer **2201**. Again the pressure/location detection circuit **602** detects the presence of a closed or open circuit; a closed circuit indicating one or more key presses in the leftmost half of the input device. An output indicative of an open or closed circuit is supplied to the switching circuit **603** which in turn conveys this information to the detection processor **601** and to output socket **507**.

The multiplex switching circuit **604** is then commanded by the detection processor to disconnect the connection to the eight leftmost attachment portions of layer **2202** and make connection from the pressure/location detection circuit **602** to the remaining seven short attachment portions **2310** to **2317**. Again an open or closed circuit is detected and the information relayed to the detection circuit **601**. A closed circuit at this stage indicates one or more key presses in the rightmost half of the QWERTY keyboard outline.

Alternatively, if one or more key presses are detected relating to either the eight leftmost attachment portions **2302** to **2309** or the remaining short attachment portions **2310** to **2317**, then the detection processor 601 performs a binary search to identify the conducting row and column intersection at which a mechanical interaction is present. The circuit does this by a process of elimination. For example, if a key press is not detected in the columns relating to attachment portions **2310** to **2317** then no further search is necessary in respect of these columns. But, if a key press is detected in the eight leftmost conducting columns relating to attachment portions **2302** to **2309**, the multiplex switching circuit **604** under the control of detection processor **601** makes a connection from pressure/location detection circuit **602** to the first four attachment portion **2302** to **2305** of layer **2201** and a second connection to the five attachment portions (**2402** to **2406**) on one side of layer **2202.** Pressure/location detection circuit then detects the presence of an open or closed circuit and provides an indicative output to detection processor **601**. The multiplex switching circuit **604**, then makes a connection from pressure/location detection circuit **602** to the next four attachment portions **2306** to **2309** of layer **2201** while maintaining the second connection to the five attachment portions (**2402** to **2406**). The pressure/location detection circuit detects the presence of an open or closed circuit and provides an indicative output to detection processor **601**.

Thus, the control circuit identifies if just one or both of the two groups of four columns is subject to a key press. If just one of the two groups is identified as relating to a key press, then this group only is interrogated and the other group is eliminated from further search. But if both groups are identified as relating to a key press, then both groups will need to be

interrogated further.

The process of binary search is continued in this manner until the identity of the individual columns relating to the key press or presses is established. A similar process is then followed to establish which of the rows contains the key press or presses. This is done by making connection of the location detection device to all sixteen attachment portions on one side of layer **2201** and a second connection to a varying number of the attachment portions (**2402** to **2406**) on layer **2202**. Having established both the row and the column, the detection processor **601** then provides an output indicating the location(s) to output socket **507** via the second switching circuit **603**. The detection processor then resets the multiplex switching circuit to its initial state in readiness for the next mechanical interaction to be detected.

By utilising this operation process, the number of connections required to be made to detect the region of the detector in which the interaction occurs is reduced compared to the time multiplexed detection of each individual region. It will be appreciated, however, that there are numerous alternative mechanisms by which the different regions of the detector are selected in order to determine the precise region within which the interaction is occurring.